Pathways to Carbon Neutral Industrial Sectors: Integrated Modelling Approach with High Level of Detail for End-use Processes

Wiese, Frauke; Baldini, Mattia

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Pathways to Carbon Neutral Industrial Sectors: Integrated Modelling Approach with High Level of Detail for End-use Processes

Frauke Wiese - Mattia Baldini
frwi@dtu.dk - mbal@dtu.dk

Systems Analysis, DTU Management Engineering

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Outline

- Background: Why modelling industrial energy use in detail?
- Modelling Approach
- Danish case
  - industrial energy use in numbers
  - location of industry in district heat areas
  - profiles of industrial energy consumption
- Discussion: Contribution to energy modelling
- Outlook and questions

Background: Industry in the energy system

- Non-residential energy demand (industry) constitutes a substantial share of total energy demand
  - EU: production and agriculture 28% / services 13% [1]
  - Denmark: production and agriculture 20% / services 13% [2]
- Usage of energy in industry is diverse regarding
  - End-use / required type of energy / temperature levels
  - Fuels
  - Temporal profiles
  - Demand flexibility
- Solutions and challenges to go 100% renewable are diverse
- Interaction with the rest of the energy system decisive

Background: Industry in integrated energy system modelling

Energy systems analysis:

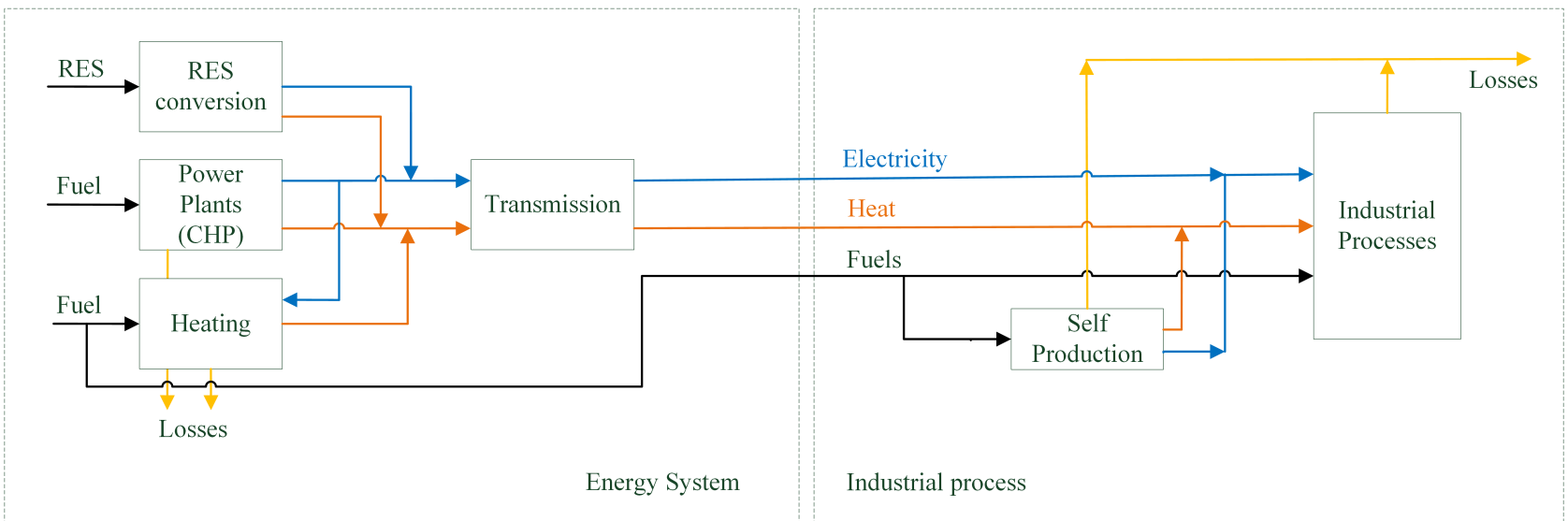
- Saving potential
- Fuel shift potential to gas, renewable gas
- Electrification potential
- Flexibility potential
- Usage of excess heat
- Usage of district heating

Integrated modelling: High level of detail required for

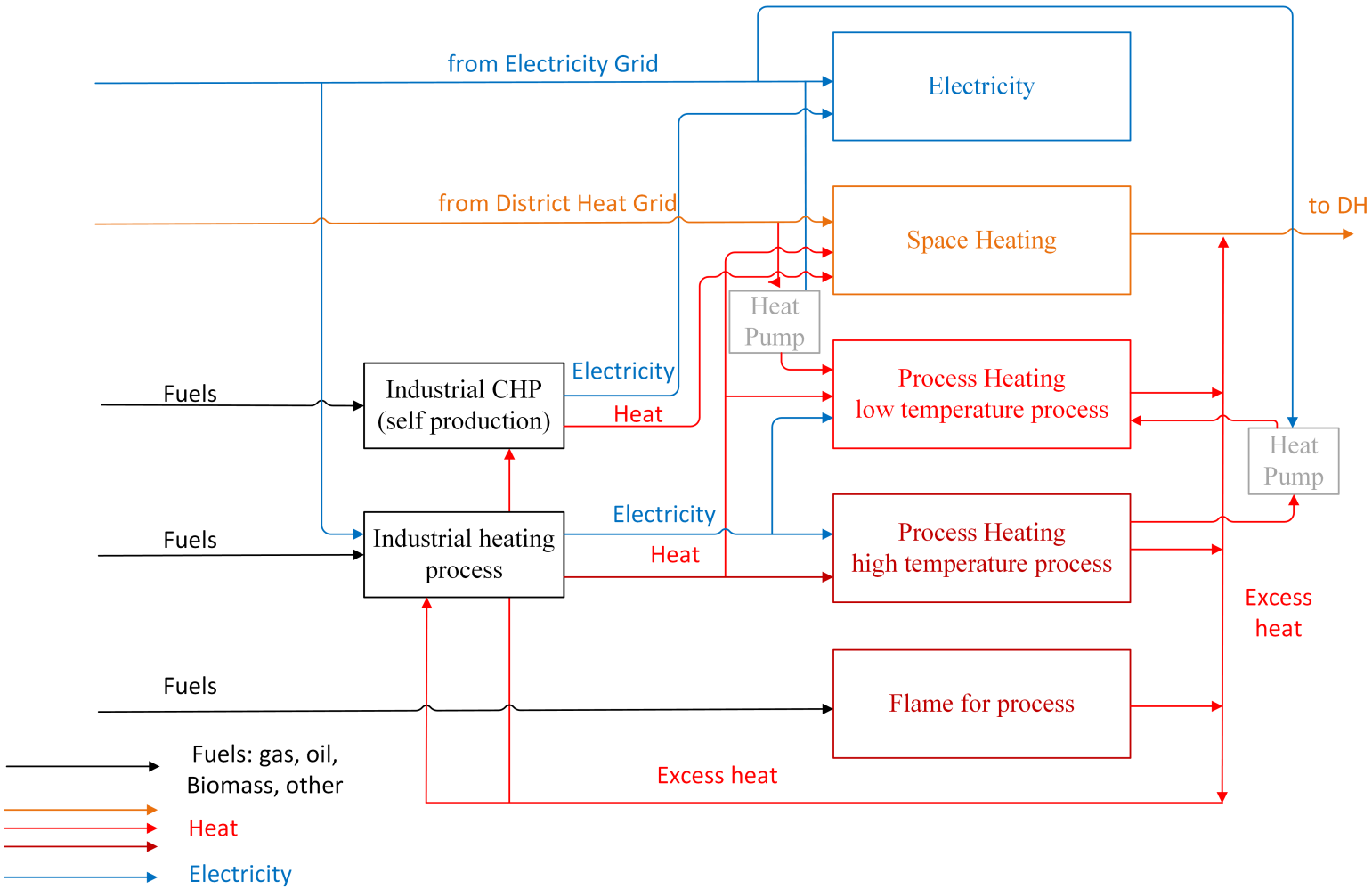
- Fuel Usage
- End-use: electricity, heat specified by temperature levels
- Time: Temporal demand profiles
- Geography: Vicinity to heat demand / district heat network
- Industry group

Modelling Approach: Balmorel extended

- Integrated Energy System Model: electricity and district heat
- High spatial resolution
- Flexible temporal resolution
- Investment and operation optimization
- Open source



Modelling Approach: Industry and Heat Transfer Addon



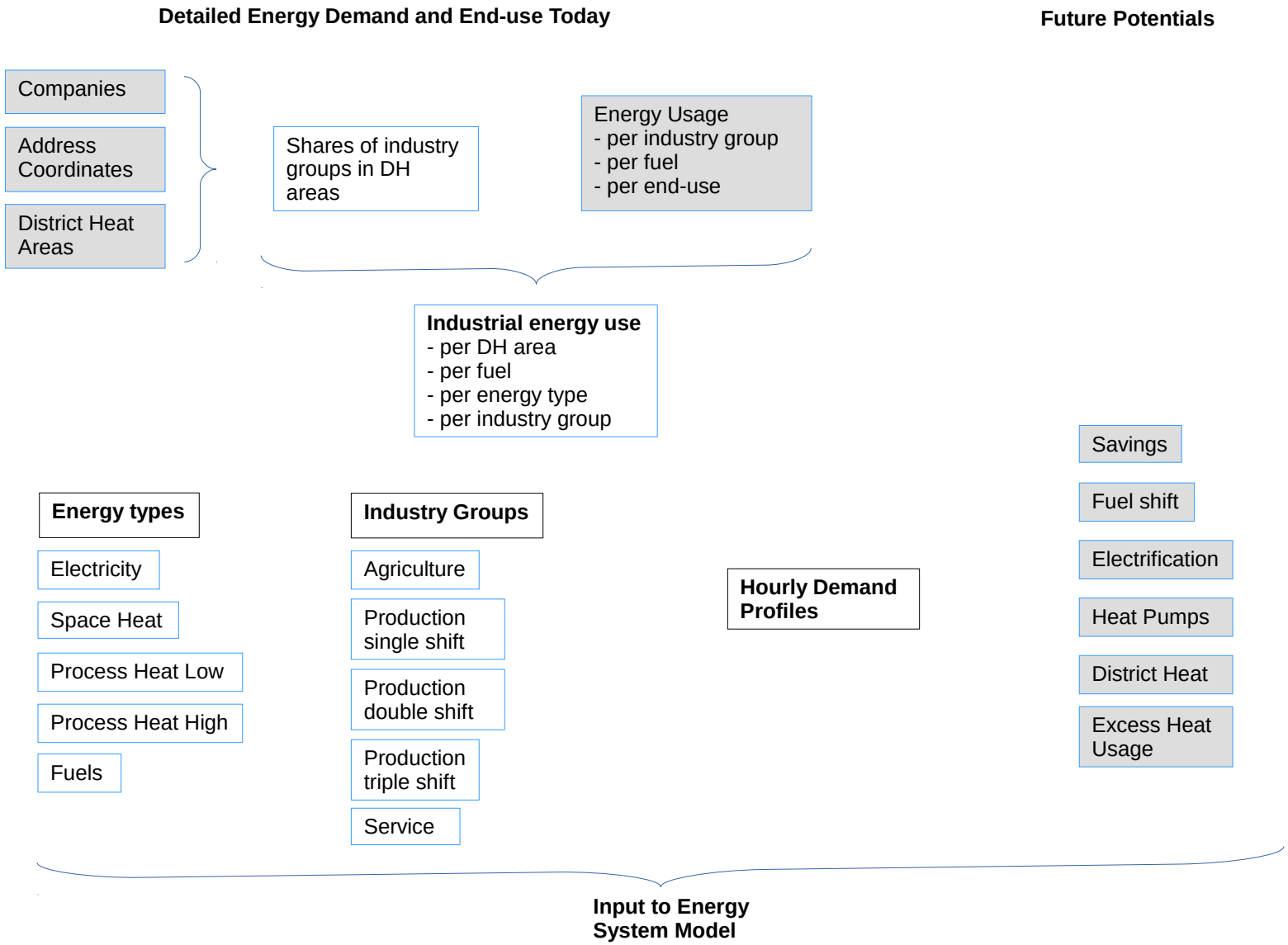
Modelling Approach: Clustering end-use by heat level

End-use	Temperature level [°C]	Model heat type
Space heating	50-90	space
Distillation	50-100	process low
Heating/Boiling	mostly 70-110	process low
Drying	about 100	process low
Inspissation	130	process low
Burning/Sintering	more than 250	process high
Melting/Casting	more than 300	process high

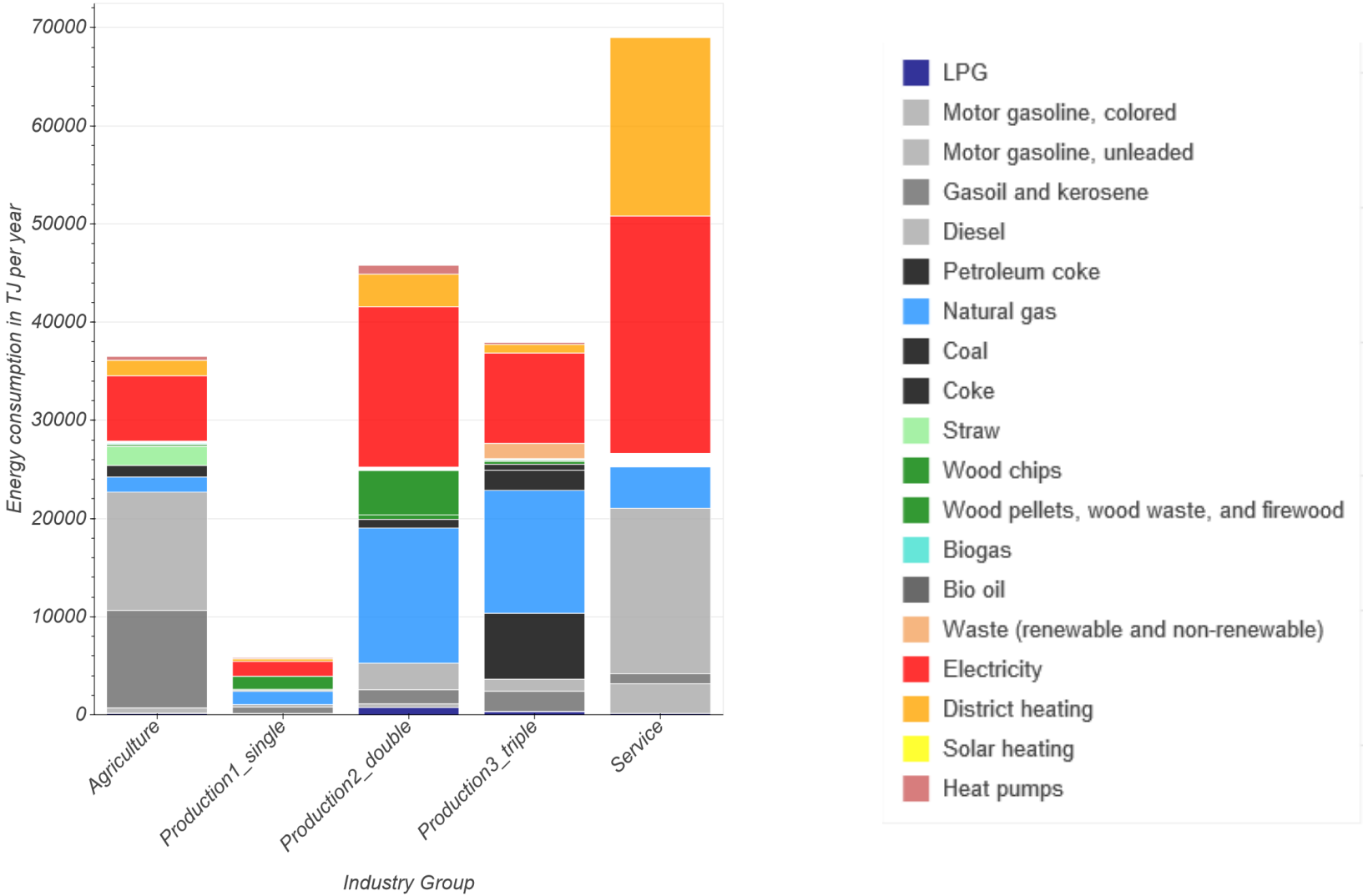
Table: Source for process heat levels:

[3]

Modelling Approach: Data Input Overview



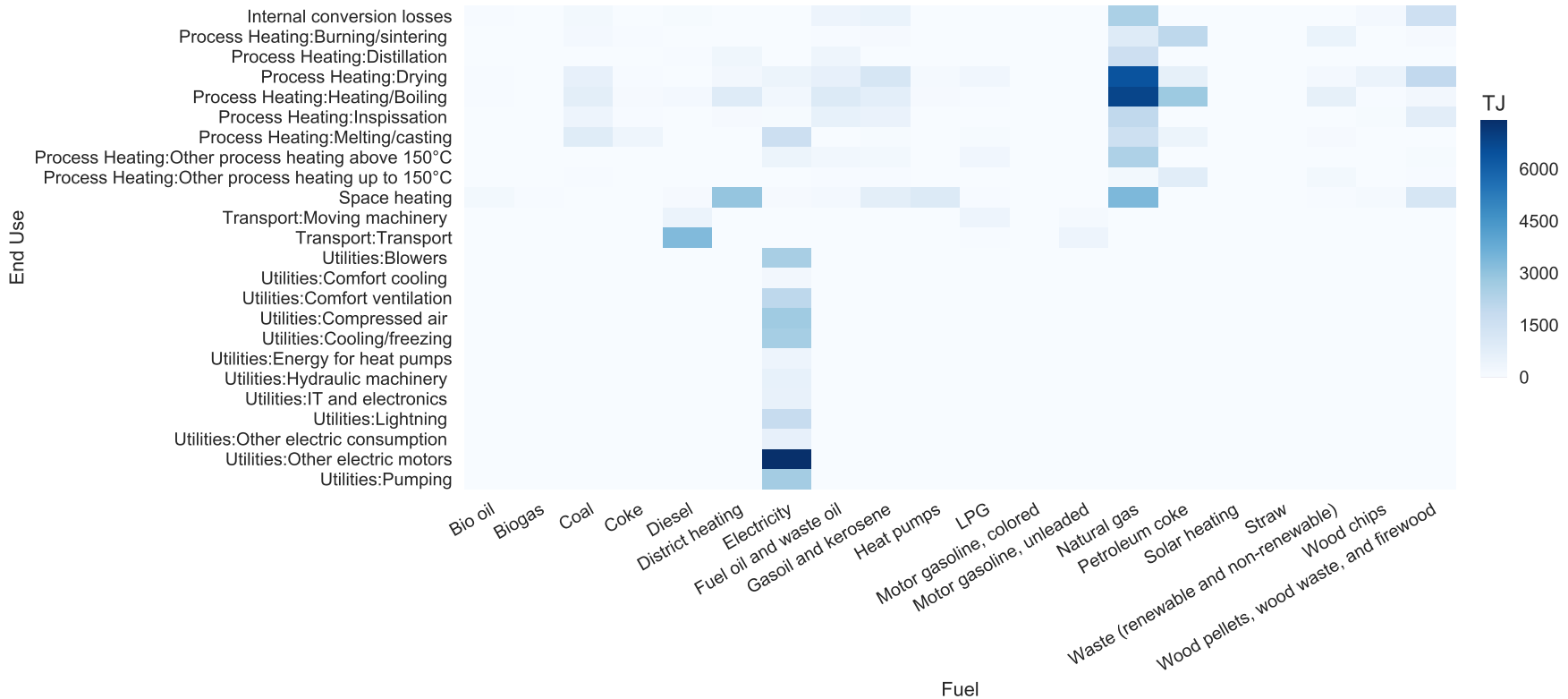
Danish case: Energy Usage by Fuel and Industry Group



Final energy use in different Danish industry groups by fuel based on data for 2012 from [3]

Production

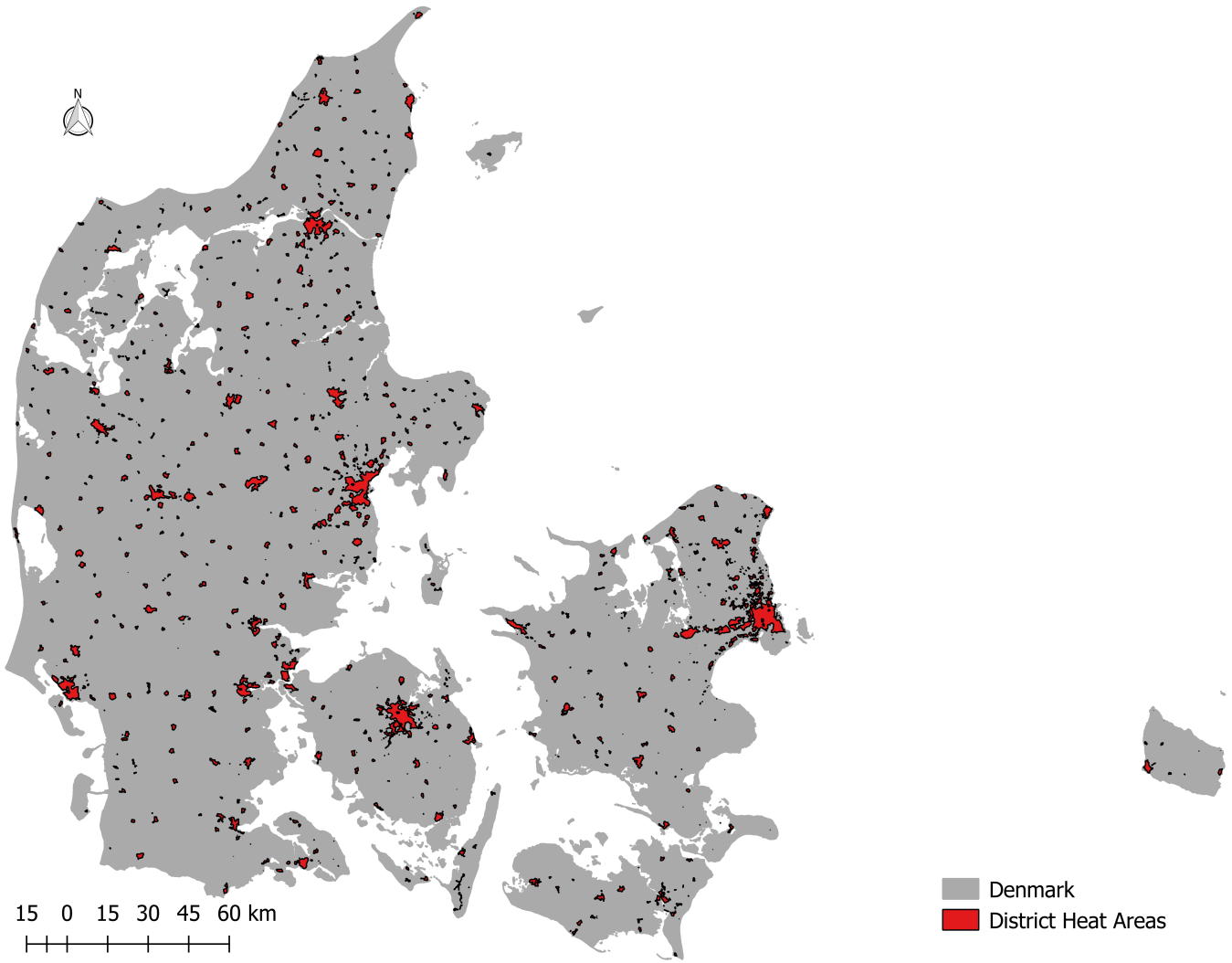
Danish Case: Energy Demand by End-Use and Fuel



- Diversity of end-use
- High share of natural gas
- High share for Drying/Heating/Boiling

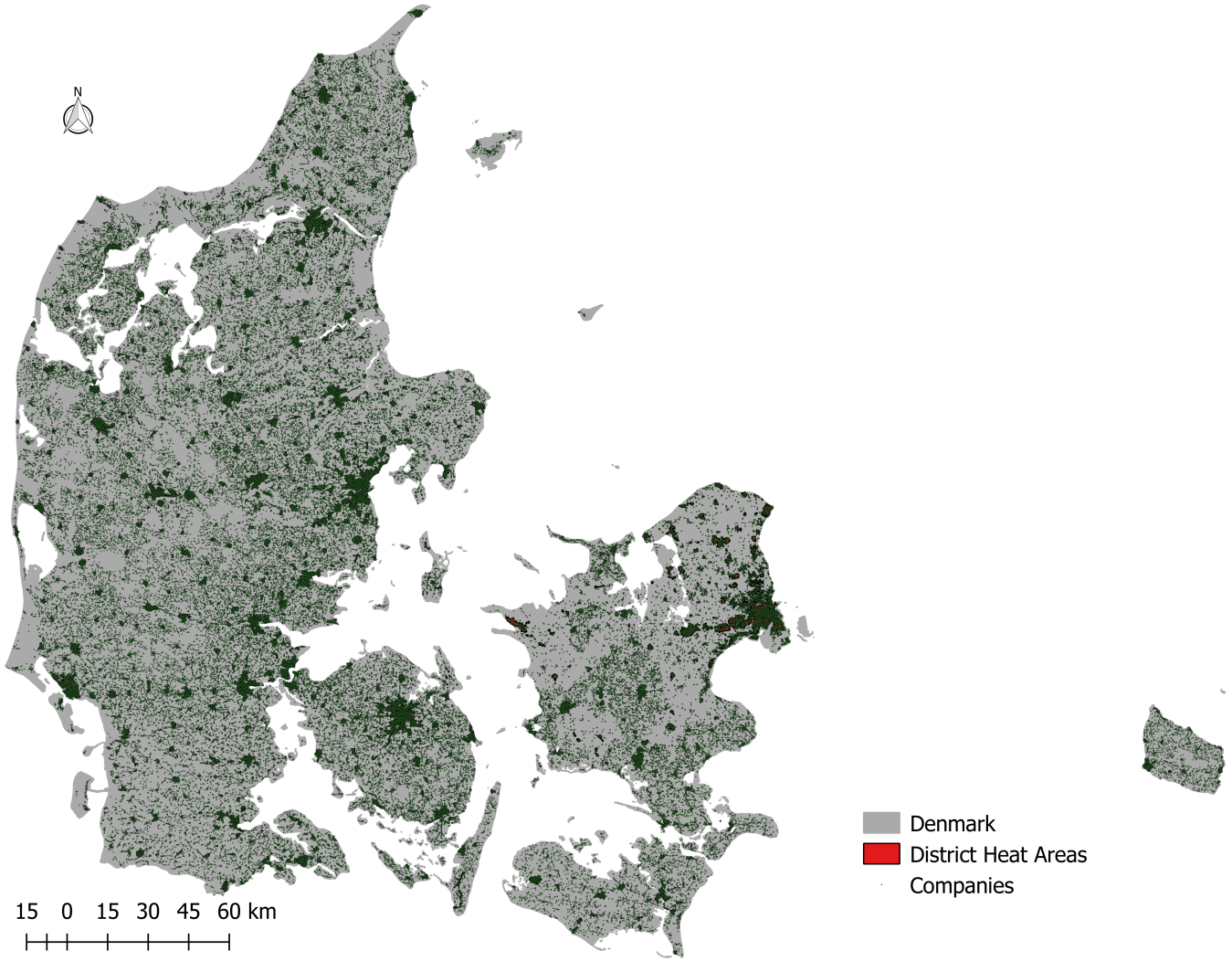
Own illustration based on data from: [3]

District Heat Areas in Denmark



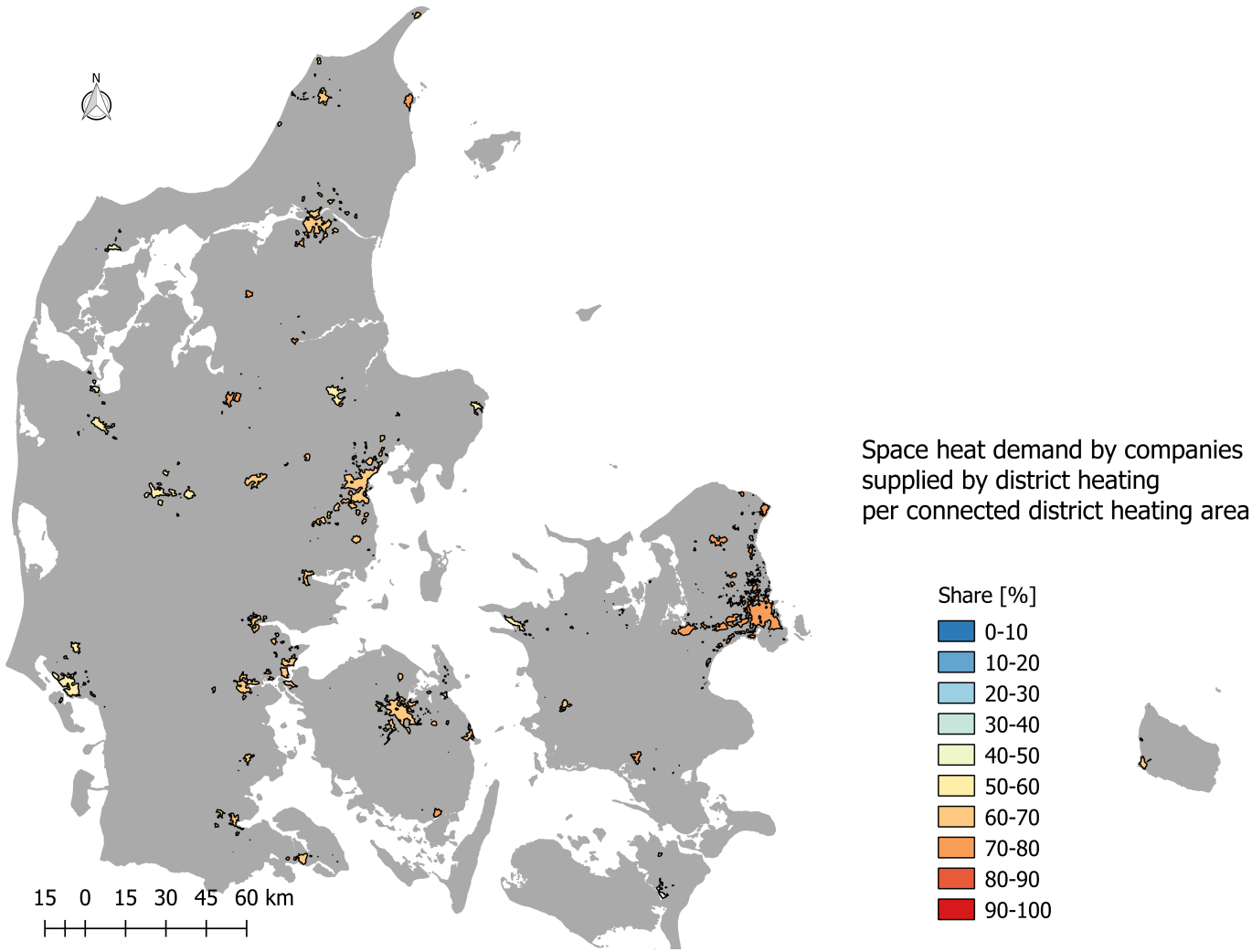
Sources: [4, 5]

Location of Companies



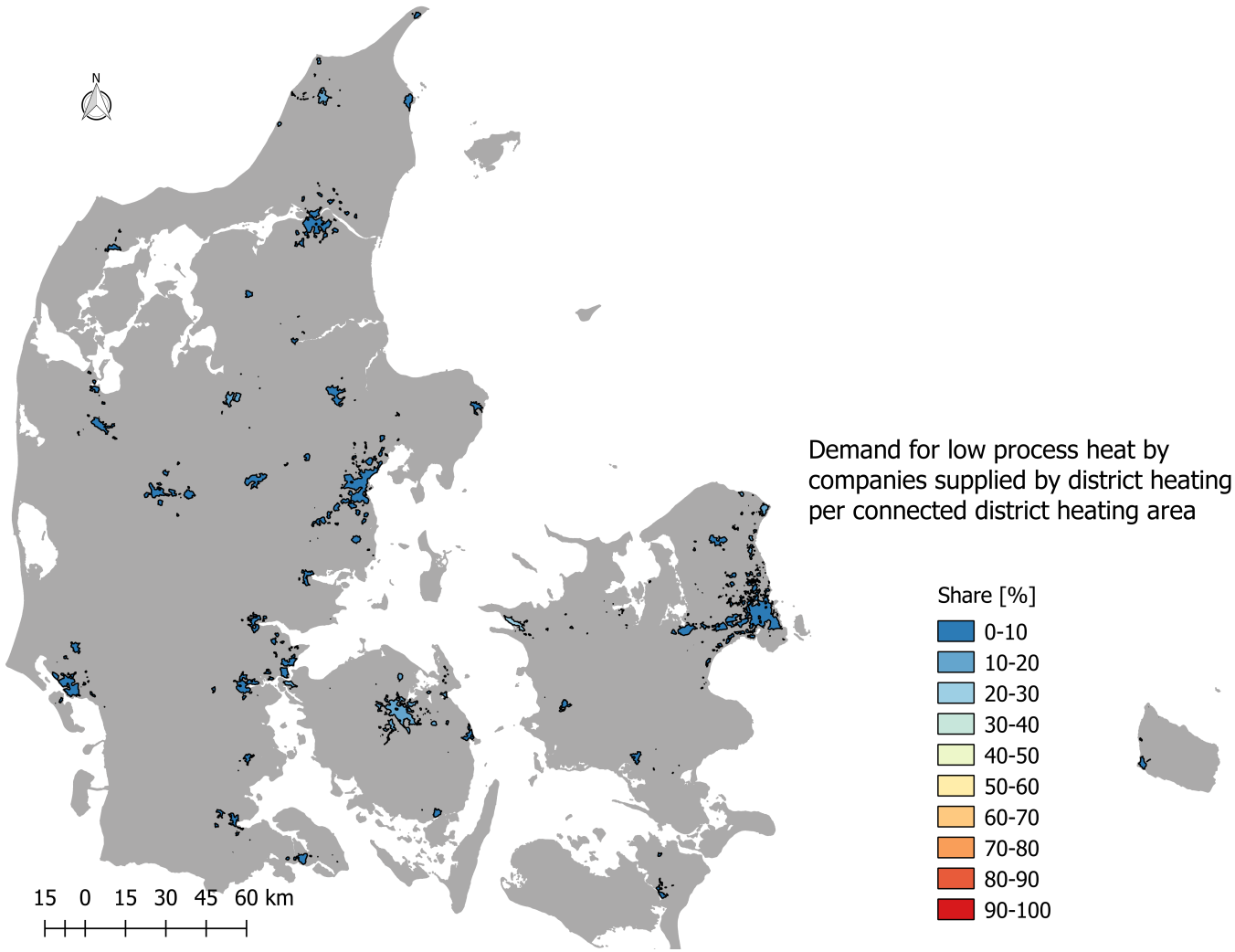
Own processing based on: [4, 6, 7, 8]

Space heat demand of companies supplied by district heat



Own calulations based on: [4, 6, 8, 9, 3, 10]

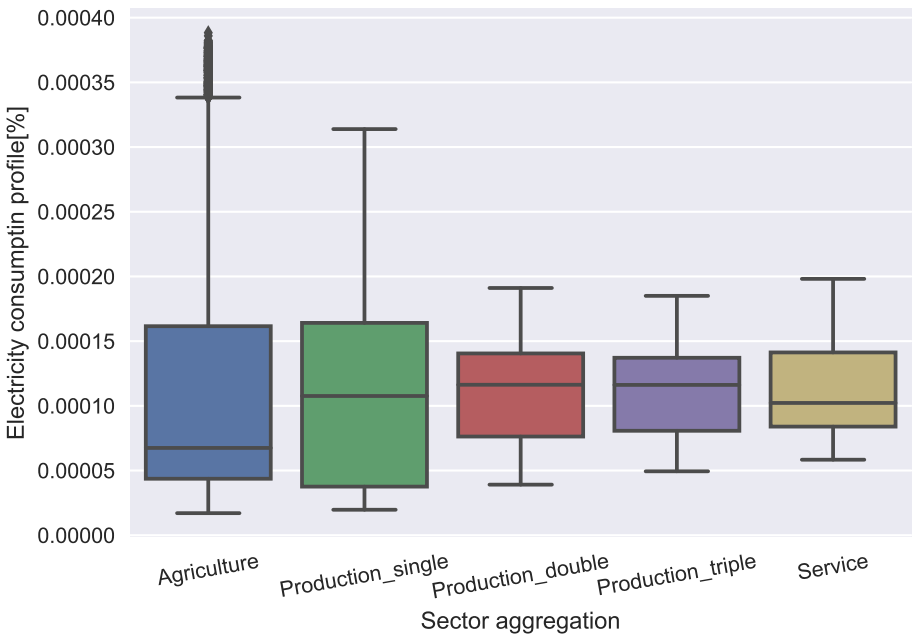
Low process heat demand supplied by district heat



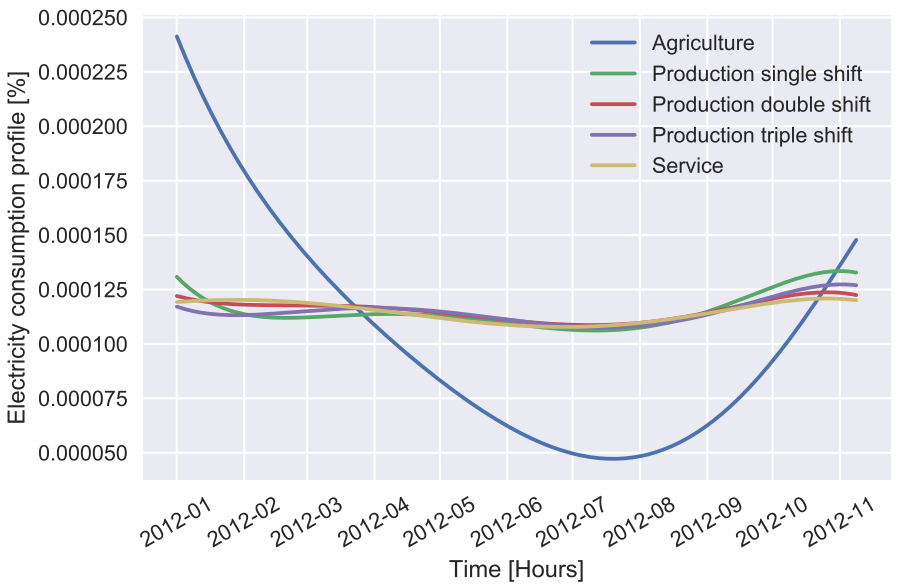
Own calulations based on: [4, 6, 8, 9, 3, 10]

Demand profiles: Electricity

Aggregated by main groups: Variability



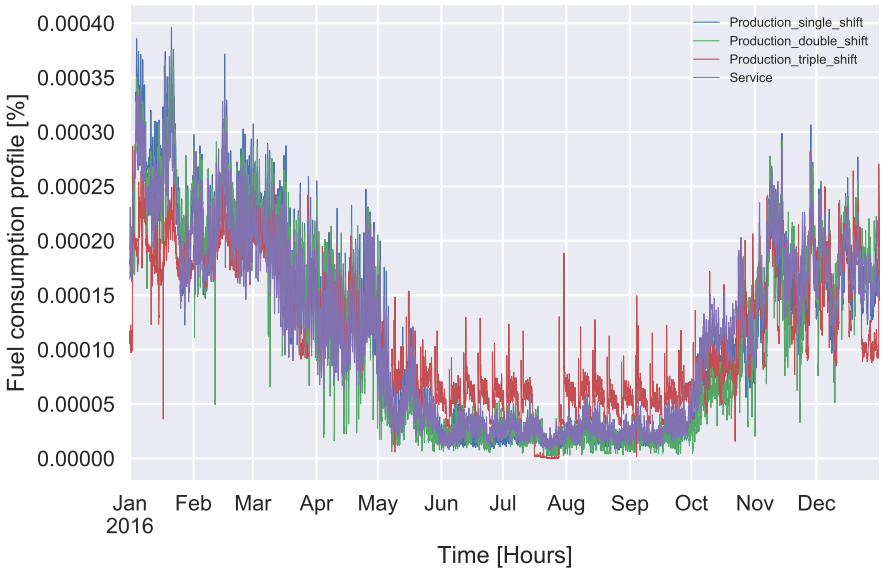
Boxplots of relative electricity consumption. Own calculations based on [11, 12, 13, 14, 15, 3]



Relative variation of seasonal electricity consumption, trend-lines (fit to the 18th order). Own calculations based on [11, 12, 13, 14, 15, 3]

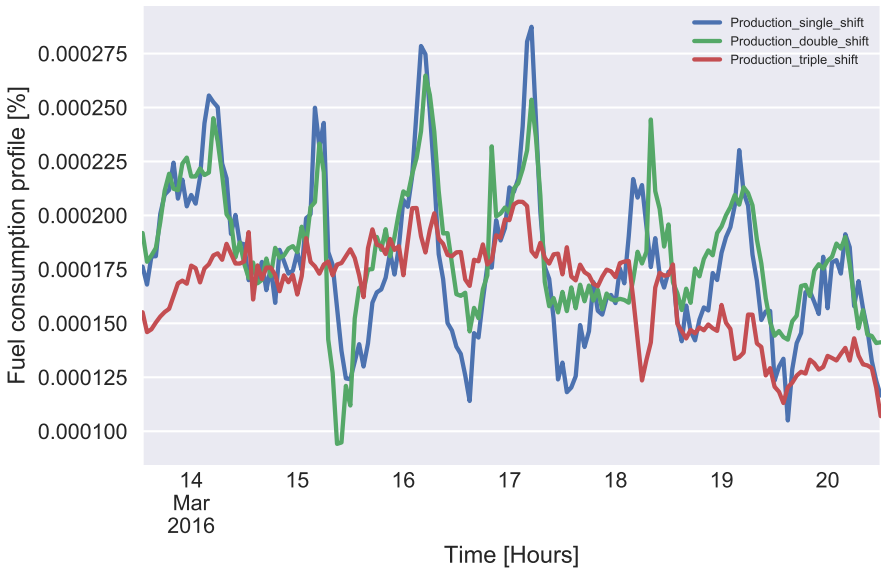
Demand profiles: Heat

Space heating, seasonal variation



Yearly scale. Own calculations based on data from

[16, 3]

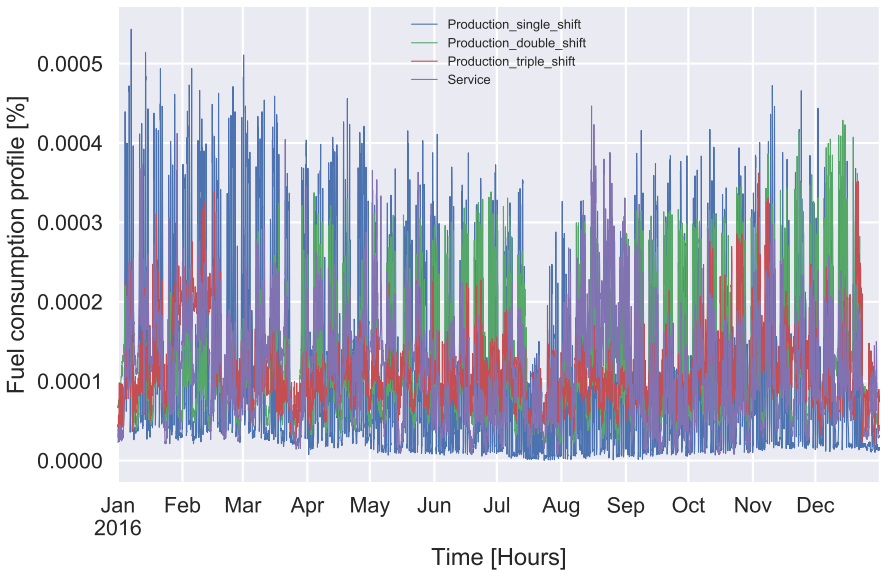


Sample week. Own calculations based on data from

[16, 3]

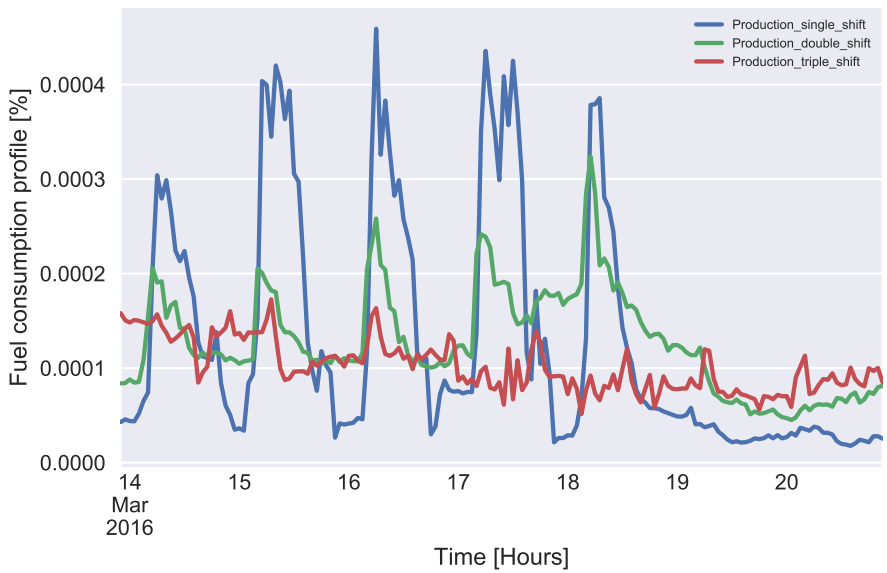
Demand profiles: Heat

Process heating, variation due to work hours



Yearly scale. Own calculations based on data from

[16, 3]



Sample week. Own calculations based on data from

[16, 3]

Discussion

- High level of detail for fuel, end-use necessary due to the diversity esp. in production
- Industry group clustering has proven useful for identification of temporal patterns
- Industry addon and detailed data enable modelling for answering important questions for energy transformation in the industry sector

Discussion: Research Questions

- Which part of companies' energy demand can be covered **by district heat** with/without extending the grid?
- From a social welfare and emission reduction point of view: What would be an advisable use of **excess heat**?
- Which **energy savings** in industry would be realized if energy system is optimized to lowest system costs?
- Which influence would a high level electrification have on **electricity demand patterns**?
- How can an electrified industry contribute to providing **flexibility** to the energy system?
- What emission reduction do fuel shift to **renewable gas**, to **bio fuels** or to **electricity** result in?

Questions

- Sources for open data on
  - saving potentials by process/end-use/industry group?
  - electrification potential?
  - future flexibility potential?
  - performance of heat pumps?
- Methods/Data sources for deriving localisation of company/industry energy demand?
  - employee share per industry group reliable?
  - emissions of large emitters?
  - ??
- Feasible distinction of heat temperature levels?

Contact: frwi@dtu.dk

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http://dx.doi.org/10.1016/j.enconman.2013.01.018

[15] F. M. Andersen, H. V. Larsen, R. B. Gaardestrup, Long term forecasting of hourly electricity consumption in local areas in Denmark, Applied Energy 110 (2013) 147–162.
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[16] Dansk Gas Distribution, Monthly and hourly gas consumption (data) (2016).